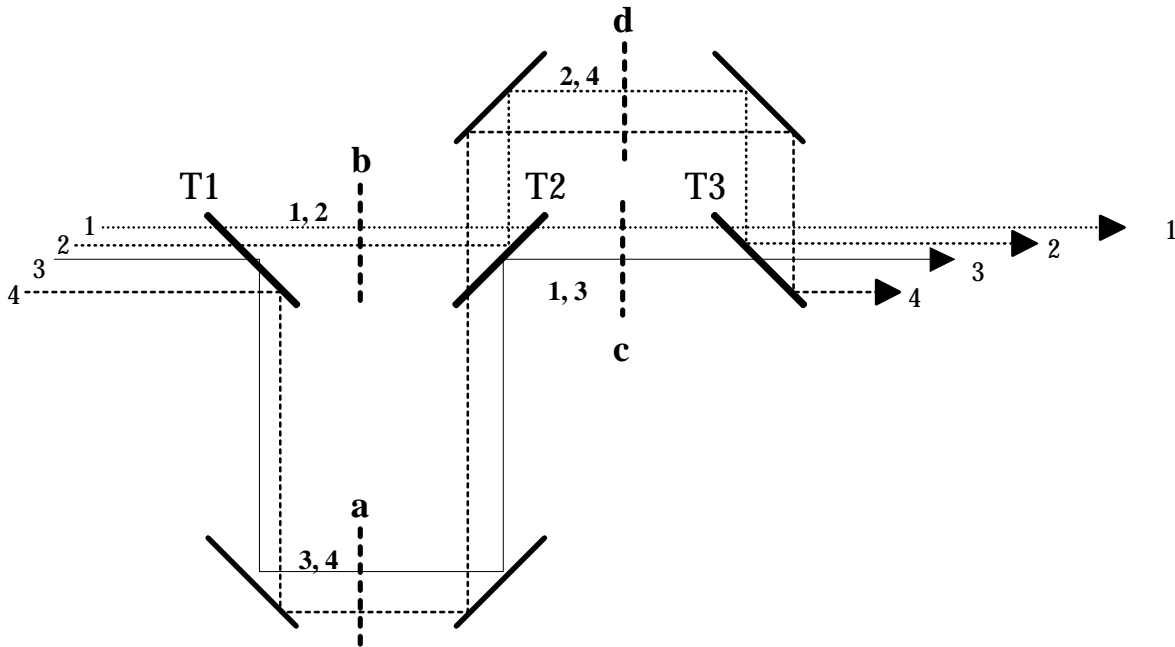


A Modified Laser Multi-splitter for Generation of a Ramped Pulse Train

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[ABSTRACT]

This AGN notes examines how to generate a ramped pulse train, of arbitrary ramping, using the existing multi-splitter [AGN-33] configuration, but with the addition of filters and different beam splitters. (The current beam splitters are 50/50 splitters.) We examine the special case of a ramped pulse train of 1, 3, 5, 7 at the end of this note.



[Figure 1] A single laser pulse enters from the left and exits the multi-splitter as 4 pulses separated by $T_{\text{RF}} = 760$ psec. The 4 laser pulses are shown separately for clarity

[INTRODUCTION]

In the modified multi-splitter, four neutral density filters (NDF's) are added in each leg with attenuation factors of a, b, c, and d, and the three 50/50 splitters are replaced with three non-50/50 splitters of Transmission coefficients of T1, T2, and T3. We will consider 3 cases: NDF's and 50/50 splitters, Non-50/50 Splitters and no NDF's, and finally using both NDF's and non-50/50 splitters.

[I] Using NDF's and 50/50 splitters

Let the intensity of any of the four beams passing through the original multi-splitter (i.e. without any filters) be I_0 . (Note that $I_0 = 1/8^{\text{th}}$ of the incoming laser intensity.) If we notice that beams 3 & 4 pass through NDF-a, beams 1 & 2 pass through NDF-b, beams 1 & 3 pass through NDF-c, beams 2 & 4 pass through NDF-d, we can write:

$$\begin{aligned} I_1 &= b*c*I_0 \\ I_2 &= b*d*I_0 \\ I_3 &= a*c*I_0 \\ I_4 &= a*d*I_0 \end{aligned} \quad \{\text{Eqn. 1}\}$$

where a, b, c, and d are the attenuation factors of the four NDF's shown in Fig. 1. Since we are most interested in the relative intensities of the pulses we examine the ratio of the first three pulses with respect to the 4th pulse. We define $r_1 = b/a$ and $r_2 = c/d$ and now rewrite Eqn. 1 as:

$$\begin{aligned} I_1/I_4 &= r_1*r_2 \\ I_2/I_4 &= r_1 \\ I_3/I_4 &= r_2 \\ I_4/I_4 &= 1 \end{aligned} \quad \{\text{Eqn. 2}\}$$

Ideally, we would like the pulse train relative intensity [1st pulse, 2nd pulse, 3rd pulse, 4th pulse] to be [1, 3, 5, 7] or relative to the 4th pulse [1/7, 3/7, 5/7, 1]. Looking at Eqn. 2 we see that the 4th condition is satisfied by definition, therefore we want to adjust r_1 and r_2 to satisfy the other three conditions. Unfortunately, there are only two “knobs” (unknowns) to adjust but three desirable intensities (equations) to satisfy. Therefore, filters alone cannot generate the desired beam. About the best we can do is let $r_1 = 3/7 \sim 0.43$ and $r_2 = 5/7 \sim 0.71$ (thus $r_1*r_2 = 15/49 \sim 0.31$). The pulse train we get is then = [0.31, 0.43, 0.71, 1] or [2, 3, 5, 7].

[II] Using non-50/50 splitters and no NDF's.

From Fig. 1 we see that beams 1 & 2 are transmitted through the first splitter, while pulses 3 & 4 are reflected at the first splitter. This means the intensity of pulses 1 & 2 after the first splitter are $T_1 * I_0$ and pulses 3 & 4 are $(1-T_1) * I_0$. Following this logic through the rest of the modified multi-splitter we can write:

$$\begin{aligned} I_1/I_4 &= x_1*x_3 \\ I_2/I_4 &= x_1/x_2 \\ I_3/I_4 &= x_3/x_2 \\ I_4/I_4 &= 1 \end{aligned} \quad \{\text{Eqn. 3}\}$$

where $x_1 = T_1/(1-T_1)$, $x_2 = T_2/(1-T_2)$, and $x_3 = T_3/(1-T_3)$. Notice that we now have 3 “knobs” so that we can form the pulse train we want. The system of equations is now:

$x_3/x_2 = 5/7$; $x_1/x_2 = 3/7$; and $x_1*x_3 = 1/7$. Solving this we get $x_1 = \text{Sqrt}[7/15]$, $x_2 = 3/7 * \text{Sqrt}[7/15]$, and $x_3 = 5/7 * \text{Sqrt}(7/15)$, or in terms of Transmission/Reflection of the mirror:

$$\begin{aligned} \mathbf{T1/R1} &= \mathbf{23/77} \\ \mathbf{T2/R2} &= \mathbf{41/59} \\ \mathbf{T3/R3} &= \mathbf{33/67} \end{aligned} \quad \{\mathbf{Eqn. 4}\}$$

[III] Using non-50/50 splitters and NDF's.

Finally, for completeness, we consider the case of using both NDF's and non-50/50 splitters. Combining the above results we get:

$$\begin{aligned} I_1/I_4 &= r_1*r_2*x_1*x_3 \\ I_2/I_4 &= r_1*x_1/x_2 \\ I_3/I_4 &= r_2*x_3/x_2 \\ I_4/I_4 &= 1 \end{aligned} \quad \{\text{Eqn. 5}\}$$

This last case is of interest in case that non-50/50 splitters are unavailable for whatever reason. Since Eqn. 5 has three equations and five unknowns it is over constrained. One way to solve this is to let $x_1 = x_3 = 1$ thus reducing Eqn. 5 to three equations and three unknowns. If we do this we have $r_1*r_2 = 1/7$; $r_1/x_2 = 3/7$; and $r_2/x_2 = 5/7$. In this case we get $r_1 = 29\%$; $r_2 = 49\%$ and $T2/R2 = 41/59$.

[CONCLUSION]

In summary, ramped pulse train of four pulses (with an arbitrary intensity ratio) cannot be generated with NDF's alone, can be generated with non-50/50 splitters alone and can be generated with a combination of both non-50/50 splitters and NDF's. It would seem that the easiest way to do this is with the technique of Section II using non-50/50 splitters only.

The desired pulse train [1, 3, 5, 7] can be generated by using three splitters:

$$\mathbf{T1/R1 = 23/77, T2/R2 = 41/59, T3/R3 = 33/67}$$